Analysis of Cut-off Points for the CAGE Questionnaire for Alcohol Abuse

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Abstract— **Physicians are in a key position to diagnose and treat patients with alcohol-related problems. Early interventions before the onset of these problems may decrease the costly health care as well as the psychological and social burden of alcoholism on the patient as well as the society. At this stage, the need for physicians to screen alcohol users systematically with a simple, effective and accurate instrument is becoming more critical. Being an easy-to-administer, low-cost, sensitive and specific screening tool, CAGE Questionnaire meets these criteria and offers the promise of raising the identification rate of alcoholic patients substantially. However, CAGE has still been reported to miss nearly half of risk-drinkers because of the incorrect setting of the high likelihood criterion for the presence of alcoholism. Therefore, there is a need to determine a clinically significant cut-off point above which CAGE will be diagnostic. This article aims to identify these optimal work-points for three different clinical settings by employing a step-wise application of statistical indices such as the area under the ROC curve, leveling factor and Youden index. This method will enable health care providers to determine the optimal CAGE scores for different treatment settings and significantly decrease the number of unrecognised at-risk drinkers.**

Keywords **– Alcoholism, CAGE Questionnaire, cut-off, leveling factor, Youden index**

I. INTRODUCTION

Alcoholism is a chronic, progressive and potentially fatal disease characterized by continued use of alcohol resulting in emotional, social, physical, or legal problems. These problems take an enormous emotional toll on individuals as well as their families, and are a great financial expense to health care systems and society in purely economic terms (1).

Early detection and identification of alcohol-related problems may alleviate ongoing medical and social problems due to drinking and reduce the future risks and costs from excessive alcohol use. This can only be possible by using a powerful screening test that coverts drinking problems and discriminates between at-risk and risk-negative alcohol users with high diagnostic accuracy. With proper screening for these conditions, physicians can identify individuals in a patient population who have begun to develop or who are at-risk for developing alcoholism.

Once they are diagnosed, patients can be treated as outpatient or inpatient depending on the complication of their alcohol-related problems. Those patients with mild-to-moderate withdrawal symptoms for uncomplicated problems and psychological stability are usually treated as 'outpatients' and assigned to support groups, counseling, or both. On the otherhand, patients with a coexisting medical or psychiatric disorder and those who may harm themselves or others, who have not responded to conservative treatments, or who have a disruptive home environment receive an 'inpatient' treatment in a general or psychiatric hospital or in a center dedicated to treatment of alcohol abuse. Since inpatient treatment is expensive, it is generally reserved for severely alcohol-dependent patients.

This paper undertakes a study on psychiatric and medical inpatients as well as elderly General Medicine outpatients. It investigates where the optimal cut-off point should be placed for these clinical settings so that physicians using the CAGE Questionnaire as their screening tool for alcoholism can achieve superior results in catching the at-risk drinkers.

II. METHODOLOGY

CAGE Questionnaire was first developed by Ewing and Rouse (2). It was initially validated by Mayfield in psychiatric inpatients (3). Then, Bush subsequently studied the CAGE using medical inpatients (4). Consequently, Buchsbaum applied the CAGE on elderly General Medicine outpatients (5). Up-to-date, CAGE has been administered to a variety of other patient groups such as college students and general populations for measuring the dimensions of their alcohol problems (6,7).

CAGE is an acronym arising from key concepts contained in each of the following four questions of the CAGE Questionnaire:

1. Have you ever felt you should Cut down on your drinking?
2. Have people Annoyed you by criticizing your drinking?
3. Have you ever felt bad or Guilty about your drinking?
4. Have you ever had a drink first thing in the morning to steady your nerves or to get rid of a hangover (Eye-opener)?

Each of the above question yields an answer in the form of binary responses as 'yes' or 'no'. Each 'yes' answer accounts for 1 point whereas each 'no' answer is given 0 points. The resulting total point is called the CAGE score. The CAGE score enables the physician to stratify patients along a continuum of risk for alcoholism: the higher the CAGE score the greater the probability of alcoholism.

Here, a dichotonomous model is used in the interpretation of CAGE scores such that all patients above an pre-determined optimal cut-off point will be assigned the same risk of positive alcoholism. This cut-off point will be defined in terms of a CAGE score such that it will alert the physician for further investigation to the high likelihood of the presence of alcoholism and portray a clinical significance. Thus,

0-7803-7211-5/01$10.00©2001 IEEE

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25OCT2001	N/A	-

Title and Subtitle Analysis of Cut-off Points for the CAGE Questionnaire for Alcohol Abuse	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Institute of Biomedical Engineering, Bogazici University, Istanbul, Turkey	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

Supplementary Notes
Papers from the 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.

Abstract

Subject Terms

Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
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practical and clinical utility of a CAGE score will decrease or increase rapidly as it deviates from this optimum point.

The choice of optimal cut-off point for a clinical setting is influenced by the relative importance of sensitivity (Σ) and specificity (Π). The values of sensitivity and specificity given for each CAGE score have resulted from that score being used as a cut-off point, so that all those with that score or above are deemed positive, and those with a lower score are deemed negative for the presence of alcoholism.

TABLE I
SENSITIVITY AND SPECIFICITY INDICES

CAGE Score	Medical Inpatients		Psychiatric Inpatients		General Medicine Outpatients	
	Σ	Π	Σ	Π	Σ	Π
4	0.200	1.000	0.370	1.000	0.250	1.000
3	0.510	0.997	0.670	0.980	0.440	0.980
2	0.750	0.960	0.810	0.890	0.740	0.910
1	0.850	0.890	0.900	0.790	0.890	0.810

The sensitivity and specificity for the studies of Bush, Mayfield and Buchsbaum calculated for one, two, three and four affirmative responses to CAGE are given in Table 1 (3-5). From the table, it reads that at least two positive answers of General Medicine outpatients to CAGE correctly identifies 74% of the alcoholics and accurately eliminates 91% of the non-alcoholics. Similarly, in the population of psychiatric inpatients, the sensitivity of an affirmative answer to one or more of the following CAGE questions is 0.90, and the specificity is 0.79. It is also observed that the medical inpatients and General Medicine oupatients yield similar specificity values while the greatest sensitivity values are achieved for psychiatric inpatients.

The effect of misclassification on diagnostic accuracy becomes more clear when Σ–values are plotted against Π on Receiver Operating Characteristic (ROC) Curves as CAGE score is varied (8). These curves are constructed and shown in Figure 1.

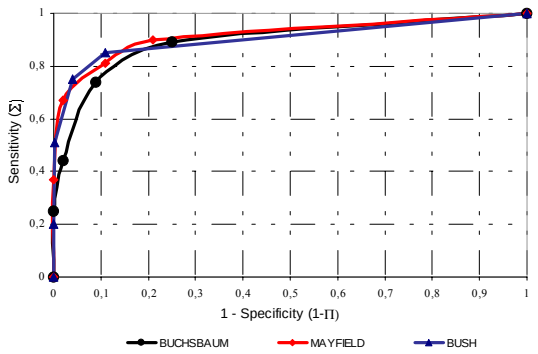

Fig. 1. ROC Curves for medical inpatients (Bush), psychiatric inpatients (Mayfield) and elderly General Medicine outpatients (Buchsbaum)

Each ROC curve in Figure 1 portrays the trade-off between sensitivity and specificity based on the CAGE performance of the corresponding clinical setting. By convention, the closer the ROC curve to the upper left-hand corner of the graph where Σ and Π are 0 and 1, respectively; it most closely approximates the perfect curve. Neither of the ROC curves displayed on Figure 1 shows a dominant superiority over the others. Rather, these curves seem to converge at some points on the ROC space. Therefore, these points are amnable for further investigation in terms of clinical significance.

In general, ROC curves may be similar (or different) over the range of clinical interest while one may be superior to (or the same as) the other over the remainder of the curve. As observed from Figure 1, there are some intervals of Σ and Π on the graph where only one of the curves displays better performance than the other two. For instance, medical inpatients portrays an ROC curve more closer to the left-hand corner of the graph between the Σ and Π ranges of 0.67-0.86 and 0.86-0.98, respectively. The same behaviour is also realized for psychiatric inpatients between the Σ range of 0.86 to 1 and Π range of 0 to 0.86. Therefore, the data stratified from medical outpatients and psychiatric inpatients yields the maximum discrimination power for CAGE between these threshold intervals with the most clinical utility.

When perpendicular distances from the upper-left corner to the curves are measured by means of employing right triangles, the best operating thresholds for medical inpatients, psychiatric inpatients and General Medicine outpatients are found at the sensitivity and specificity of (0.84;0.91), (0.79;0.90) and (0.77;0.91), respectively.

III. DISCUSSION

Leveling Factor Analysis, a deterministic statistical method that incorporates logistic regression, is employed for the identification of optimal cut-off points for psychiatric inpatients, medical inpatients and elderly General Medicine outpatients. This method is a type of log-linear analysis and predicts the categorical dependent variable (Δ) on the basis of two independent variables, i.e. Σ and Π by using the maximum likelihood estimation method (9). Thus, Δ will be calculated at linear combinations of Σ and Π where the probability of misclassification between alcoholic and non-alcoholic patients is minimised. The leveling factor statistics, Δ, can be obtained as follows:

$$\Delta = \frac{1}{1+\sqrt{(\frac{1}{1-\Sigma}-1)(\frac{1}{1-\Pi}-1)}} \qquad (1)$$

Another index that will be incorporated in this study is the Youden Index, Ψ. In the context of screening, the CAGE score with the highest Ψ, should capture the highest number

of patients with disease and individuals without diease while minimizing the risk and cost for capturing patients without disease and individuals with disease. For hypothetical diagnostic tests, it has been found that a maximized Ψ–statistics should occur at a point where Δ is also maximized (10). The Ψ–statistics is calculated as follows:

$$\Psi = 1 + \Sigma - \Pi \qquad (2)$$

Leveling factors (Δ) and Youden Indices (Ψ) for one, two, three and four affirmative responses to CAGE are calculated for psychiatric inpatients, medical inpatients and elderly General Medicine outpatients for the selection of an optimal borderline CAGE score for the positive screen of alcoholism and illustrated in Table 2.

TABLE II
LEVELING FACTOR AND YOUDEN INDICES

CAGE Score	Medical Inpatients		Psychiatric Inpatients		General Medicine Outpatients	
	Δ	Ψ	Δ	Ψ	Δ	Ψ
4	0.020	0.200	0.013	0.370	0.017	0.250
3	0.051	0.507	0.091	0.650	0.139	0.420
2	0.105	0.710	0.146	0.700	0.144	0.650
1	0.129	0.740	0.147	0.690	0.146	0.700

As indicated in Table 2, lower CAGE scores provide better discrimination for alcoholism yielding higher values for Δ and Ψ. A positive response to at least one CAGE question with a Δ–value of 0.129 and Ψ–value of 0.74 is an indicator of alcohol dependence in the medical inpatients. Therefore, the recommended CAGE score of 1 is a reasonable approximation to the optimal cut-off point for medical inpatients. Since the highest Δ and Ψ values yield very close results for psychiatric inpatients at the CAGE scores of 1 and 2, the optimal cut-off can be chosen according to cost, convenience and risk of using that point. As for the elderly General Medicine outpatients, one affirmative answer to the CAGE should alert the physician for positive alcoholism as validated by a Δ–value of 0.146 and Ψ–value of 0.70.

IV. CONCLUSION

Translating the CAGE scores into quantitative performance indices such as the leveling factor and Youden Index enhances the richness of the information available to the physicians. By interpreting the discriminating power and clinical utility of each score, they can now develop more proper and effective clinical settings in identifying patients who have begun to develop or who are at risk for developing alcoholism.

Setting optimal cut-off points for each treatment setting, such as in this study, will significantly diminish the number of risk-drinkers that could not be identified by previous methods earlier. This will lower the morbidity, mortality and health care costs as well as preventing progressive damage to social relationships.

Future work will concentrate on the diagnostic accuracy of the CAGE questionnaire. Standardizing these findings as screening protocols will minimize the time, effort and costs for diagnosis and intervention to alcoholism.

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